

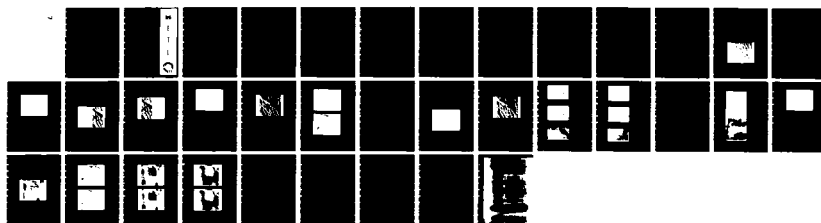
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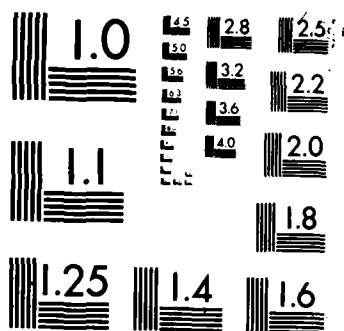
ANALYSIS OF INTERACTIVE IMAGE CLEANSING VIA  
RASTER-PROCESSING TECHNIQUES(U) ARMY ENGINEER  
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Analysis of interactive  
image cleansing via  
raster-processing techniques

Nancy J. Friend

NOVEMBER 1983

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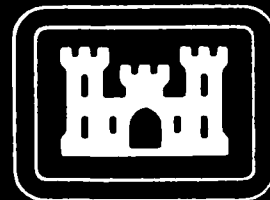
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An analysis of an interactive image-cleansing program, RASTER, is presented. RASTER is utilized for cleansing binary imagery in a fast and effective manner via nine programed functions, which are herein described and illustrated.		

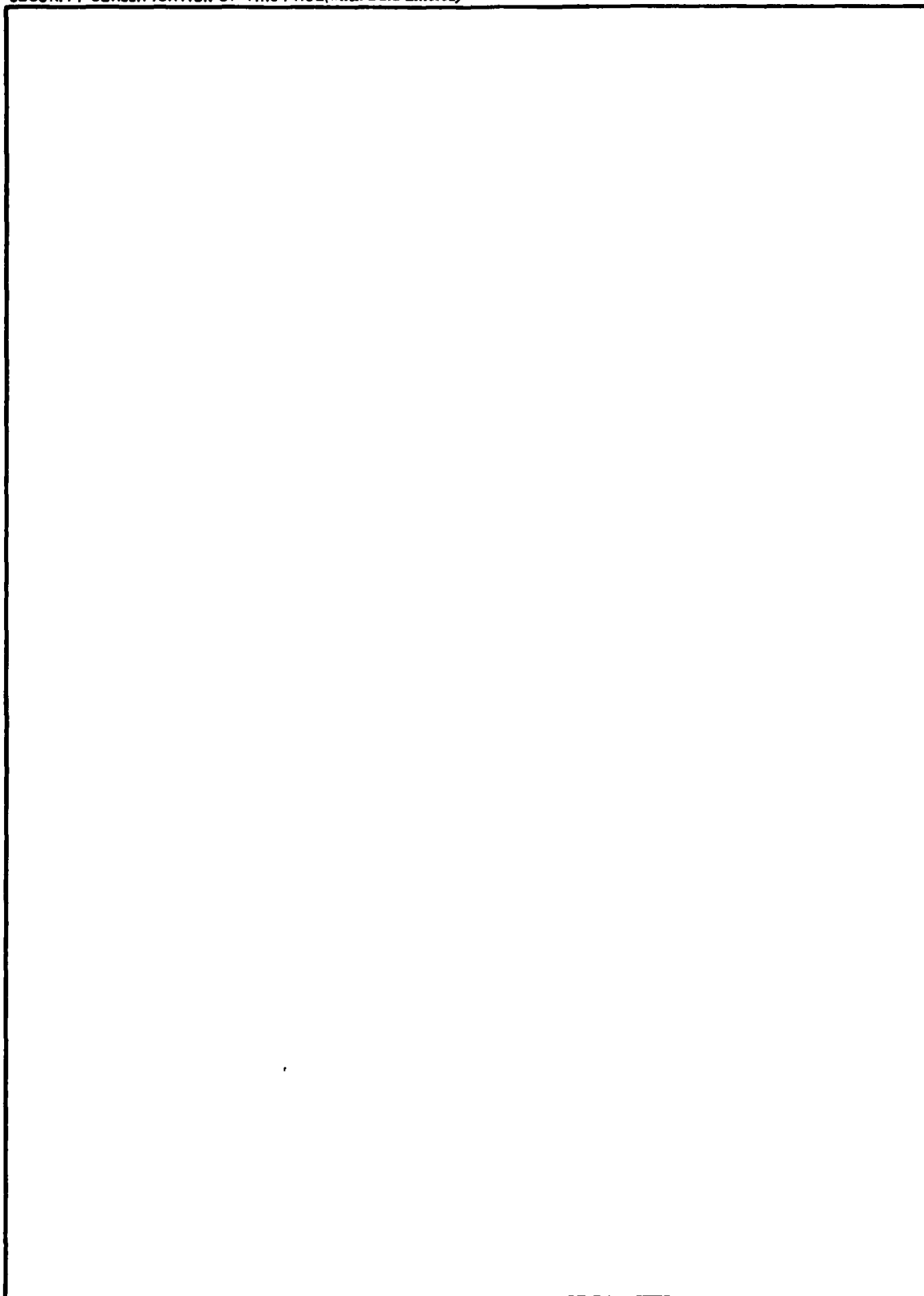
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# PREFACE

This study was conducted under DA Project 4A762707A855, Task B, Work Unit 0026, "Topographic Mapping Techniques."

The study was done during 1982 under the supervision of Mr. Dale E. Howell, Chief, Information Sciences Division; and Mr. Lawrence A. Gambino, Director, Computer Sciences Laboratory.

COL Edward K. Wintz, CE, was Commander and Director and Mr. Robert P. Macchia was Technical Director of the Engineer Topographic Laboratories during the study and report preparation.



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## ANALYSIS OF INTERACTIVE IMAGE CLEANSING VIA RASTER-PROCESSING TECHNIQUES

### INTRODUCTION

Resultant images from studies conducted in the areas of classification and linear edge detection using several different algorithms indicate a need for an efficient, interactive image-cleansing program. Since no algorithm is perfect, points will be misclassified and edges incorrectly identified. In addition, other errors will be introduced because of clutter in the data. An attempt was made to remove some of these ambiguities via relaxation techniques,<sup>1</sup> which yielded some improvement; however, a need for further cleansing was indicated. The interactive feature of the image-cleansing program enables the user to experiment with noisier, less expensively derived images in both the areas of classification and linear edge detection in an effort to produce satisfactorily cleansed imagery.

The Engineer Topographic Laboratories (ETL) interactive, image-cleansing program is called RASTER because it processes data in a raster format in lieu of a vector format. Imagery derived from past classification and edge-detection studies will be used to demonstrate RASTER's capabilities (see References for additional information on the derivation of these images).

---

<sup>1</sup>Azriel Rosenfeld, Robert A. Hummel, and Steven W. Zucker, "Scene Labeling by Relaxation Operations," IEEE Transactions on Systems, Man and Cybernetics, VOL. SMC-6, June 1976.

## THE RASTER PROGRAM MODULE

The RASTER Program Module (PM) was programed under contract by Goodyear Aerospace Corporation (GAC) for the STARAN associative array processor. The STARAN is a high-speed processor that uses a series of memory arrays, which permit the user multidimensional access to all data stored in the arrays. This characteristic makes the STARAN ideally suited for processing raster data because such data is generated in an array format. It should, however, be emphasized that ETL's concern was not centered on efficiency of the computer code, but rather it was centered on the practicality of a semi-automated approach to feature extraction allowing for manual intervention through interactive display devices.

The RASTER PM is implemented on ETL's Digital Image Analysis Laboratory (DIAL). RASTER requires two display devices, binary imagery, and 74K words of memory. As previously mentioned, the software was written for ETL's associative array processor, STARAN. The STARAN computer is interfaced to the host computer of DIAL, the CDC Cyber 730, and operators communicate with it through the interactive, soft-copy terminals of the DIAL facility.

The RASTER PM enables the user to select various raster functions (either to be executed singly or in combinations of up to 16 functions per iteration), to execute these functions, and to display the results. At this point, the user may choose to return to the original image and select an alternate set of functions for processing or if satisfied with the present results, may continue processing with this newly created image.

Currently, there are nine RASTER functions available for use. These functions are listed in table 1. Following this table is a brief discussion of how each of these functions operates on binary imagery<sup>2</sup> followed by split-screen photographs of imagery before (left) and after (right) processing the particular function being described.

---

<sup>2</sup>Descriptions of the operation of RASTER functions were taken from "User's Guide, DIAL: Staran Interactive RASTER Processing" prepared by Dick Lott, Goodyear Aerospace Corporation, 1981.

**TABLE 1. Available RASTER Functions**

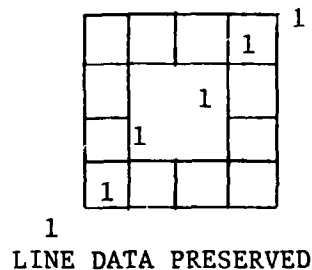
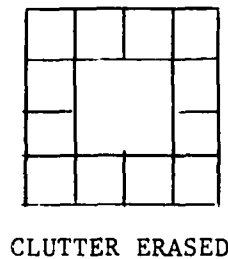
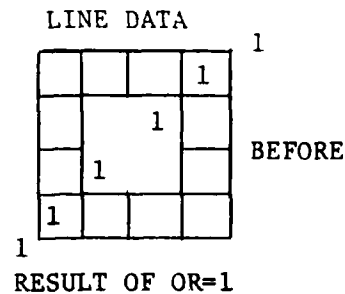
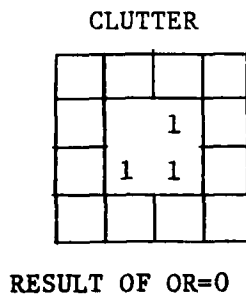
CLUTTER ELIMINATE  
THICKEN  
LINE THIN  
LINE SEGMENT ERASE  
CLEAR INTERIOR POINTS  
NEGATE IMAGE DATA  
CLEAR ALL POINTS  
SET ALL POINTS  
TWO-CELL THICKEN

Binary data derived from Phoenix, Arizona, imagery will be used in the following discussion to illustrate various RASTER functions. The intent of studying this imagery was to isolate drainage patterns. This image is provided in figure 1 for reference.



**Figure 1. Right-bit gray shade image of Phoenix, Arizona.**

**Clutter Eliminate.** This function is used to erase noise or unconnected raster bit patterns of various size. Essentially, a box is drawn around the raster data, and if no raster data passes through or lies on the box (i.e. the logical OR of the bits on the box is zero), all interior data is erased. An example of a 4 by 4 box is shown:



The sizes of a box specified by the user must be in the range

$$4 \leq \text{box size} \leq 82$$

cells on an edge. Holes in raster data may be "erased" by first negating the image, by using clutter eliminate, and then negating the image back to its original state. The execution time in a four-array STARAN for three box sizes is

Box Size	Time (Nanoseconds)	Time for full 512**2 image (32-bit overlap)
4	8.5	6.3 milliseconds
8	15.9	10.6 milliseconds
16	30.0	19.2 milliseconds

The image in figure 2 illustrates the execution of the clutter eliminate function using a box size of 15.



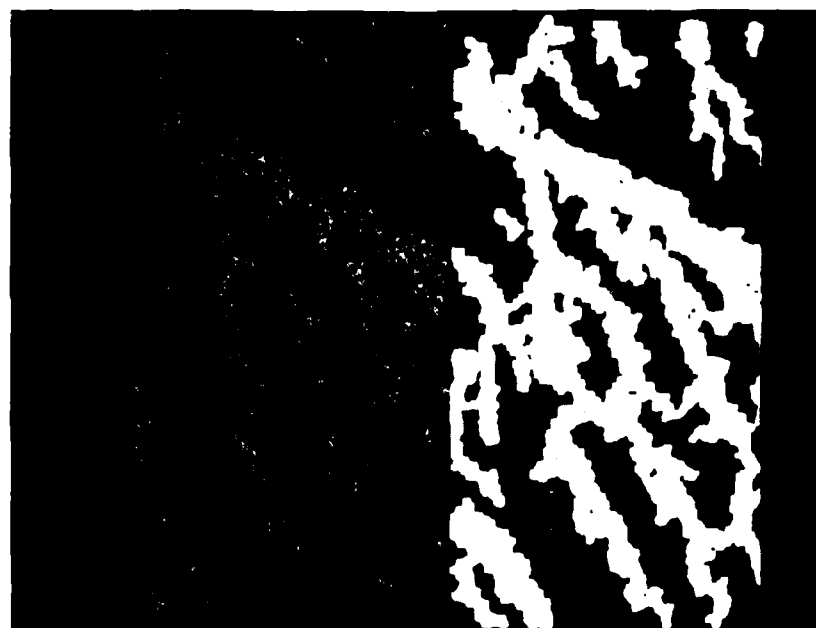
Figure 2. Before/After execution of the clutter eliminate option.

**Thicken.** This function can be used to join line breaks or fill in areas with holes. The number of "3-cell thicken" repetitions is requested and entered by the user. A 3-cell thicken operation is depicted:

0 0 0	1 1 1
0 1 0	1 1 1
0 0 0	1 1 1
BEFORE	AFTER

The center value of an arbitrary 3 by 3 cell of binary data is logically ORed into its eight neighbors. The execution time required to perform this operation for a single 3-cell in a four-array STARAN is approximately 2 nanoseconds and approximately 1.5 milliseconds per pass for a full 512\*\*2 image with 32-bit overlap. An example of a line segment before and after a single 3-cell thicken operation is shown in figure 3.

		1 1 1
1		1 1 1 1
1		1 1 1 1 1
1		1 1 1 1 1
1	1 1 1 1 1 1 1 1 1	
1 1 1 1 1	1 1 1 1 1 1 1 1	
	1 1 1 1 1 1 1	
BEFORE	AFTER	



**Figure 3. Before/After execution of the thicken option.**

**Line Thin.** Line-thinning can be used to reduce a "thick" line of arbitrary pixel width to a center line that is no more than 1 pixel in width. The user may optionally specify, and thus limit, the number of "3-cell-thinning" repetitions, which normally continue until all data have been reduced to a single cell in width. There are 256 different cases of an arbitrary 3 by 3 cell with a bit set in the center. The decision whether or not to erase a "center pixel" is made by the thinning algorithm for all 256 cases, simultaneously. In a four-array STARAN with 1024 words of associative memory, there are 1022 possible 3 by 3 cells in a column,

and all are processed in parallel. The execution time to thin an arbitrary 3-cell is approximately 9.5 nanoseconds. The execution time for an entire 512\*\*2 image with 32-bit overlap may range from as low as 7 milliseconds for one thinning pass to as high as 844 milliseconds for 120 passes on raster data, which have all pixels set to one.

The imagery in figure 4 demonstrates how a previously "thickened" image can be reduced to a center line that is 1 pixel in width.

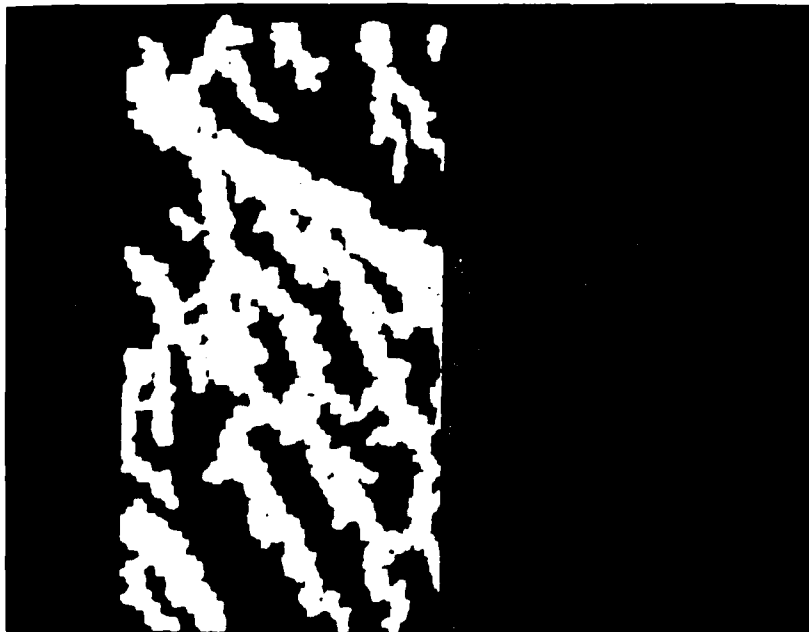
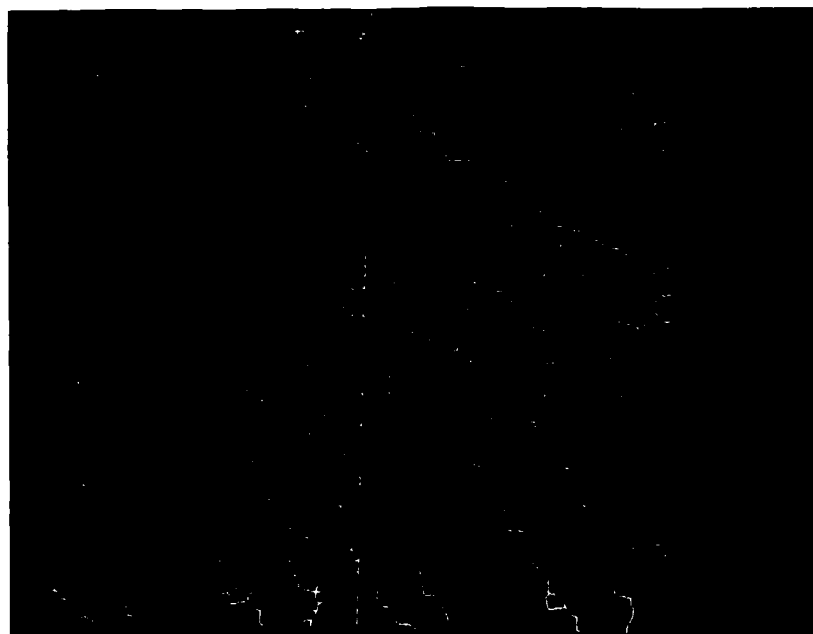


Figure 4. Before/After execution of the thin option.

**Line Segment Erase.** This function should only be used upon data that has been thinned to center line data of no more than 1 cell in width. Unconnected line segments, as well as short segments that intersect or join other line segments, may be erased. The user must enter the length of line segments to erase.

This length may range from 2 to 82. All segments whose length is less than or equal to the value entered will be erased. An example of line segment erase with a length of 3 specified is shown in figure 5.

1 1	1	
1		1
1 1	1 1	
	1	1
	1	1 1 1 1
1	1	1
BEFORE		AFTER



**Figure 5. Before/After execution of the line segment erase option;  
line segment = 10.**

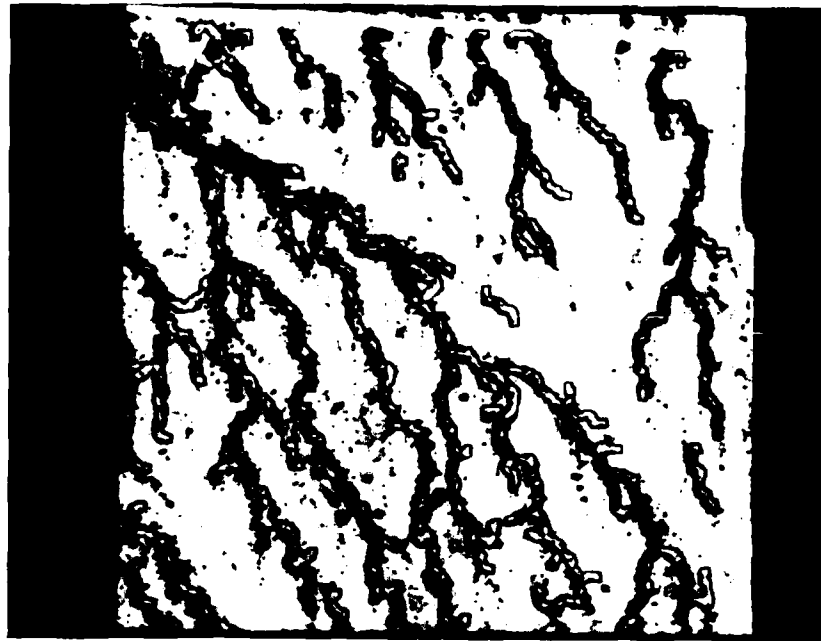
**Clear Interior Points.** This function can be used to obtain boundaries between regions or clusters of raster data. An interior point is defined to be the following 3 by 3 cell:

? 1 ?	? 1 ?
1 ? 1	1 0 1
? 1 ?	? 1 ?

BEFORE

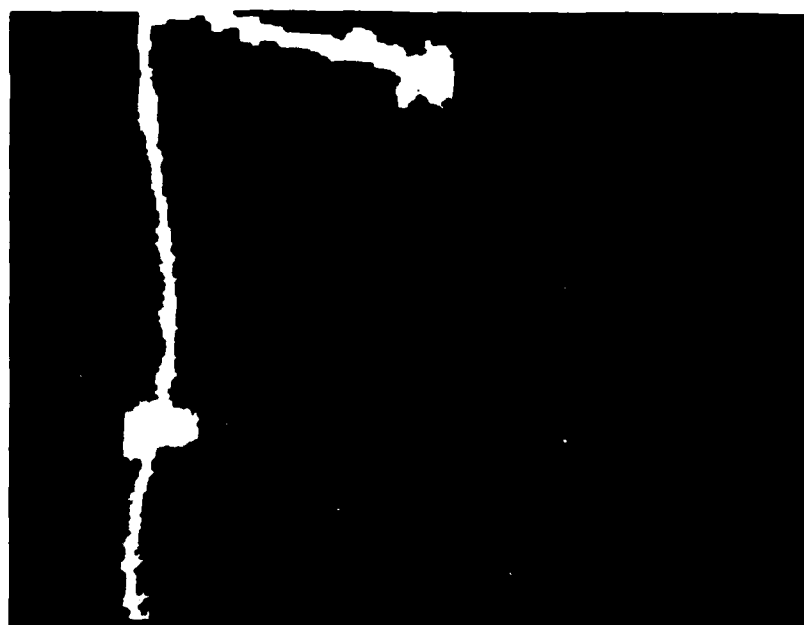
AFTER

This question marks refer to "don't care" raster values. The center cell of all such 3 by 3 cells is considered to be an interior point and is cleared. The execution time for an entire 512\*\*2 image will be approximately 1.75 milliseconds (figure 6).



**Figure 6. Demonstration of clear interior points option.**

**Two-Cell Thicken.** This is a special case of the thicken option where each pixel is thickened twice in the x and y direction. The need for using this option arises from problems created by DIAL's display limits of 512 x 512 and the subsequent procedure for resampling images larger than 512 x 512. If the RASTER data on 1024 x 1024 images have been processed to leave lines of data which are a single pixel in width (e.g. by thinning to a center line or by clearing interior points), then this resampling may cause these lines to appear disjointed. Hence, to insure continuity of data, which is 1 pixel wide on images that will have to be resampled for display purposes, the user must thicken the image with the 2-cell thicken option. The example below illustrates the disjoint appearance of a resampled image after clearing the interior points and the correction of this display problem as a result of executing the 2-cell thicken option. (Note: This example uses different imagery as it was necessary to select a 1024 x 1024 image and the Phoenix imagery used in previous examples is 512 x 512.)



**Figure 7.** Original binary imagery and Before/After execution of 2-cell thicken on a resampled 1024 by 1024 image.

The remainder of the RASTER functions, namely negate, clear all points, and set all points, will not be illustrated as they can be easily envisioned.

**Negate Image Data.** This function complements the value of all raster data. It is useful along with clutter eliminate as a tool for handling certain cases.

**Clear/Set All Points.** These two functions are provided in support of various subimage raster-processing tasks. It would not make sense to use these functions on an entire image as all of the original data would be destroyed. Clear all points can be used for clearing in areas larger than the maximum box size that can be specified for clutter eliminate. Also, setting all points might be more convenient than using several repetitions of the thicken function.

In addition to these nine processing functions, the RASTER PM also allows for three major special purpose functions.

The first special purpose function is to save the resultant image as a permanent DIAL file enabling the user to return at a future time to complete processing or to display the final image.

The second function is to alter the STARAN array usage, which enables the default of using all four of the STARAN arrays to be altered if there is a malfunction localized in one or more of them. The user must choose a contiguous group of array memory modules from any of the four arrays numbered 0, 1, 2, and 3. The user may select to use from one to four memory arrays for processing as long as they are contiguous, i.e. arrays 1 and 2; or 0, 1, and 2; or just 3, but not 0 and 2. The degradation in processing performance is negligible for RASTER-processing functions when less than the default of four arrays is used because of the I/O rates.

The third function allows the selection of a rectangular subimage for localized RASTER processing. Only the selected subimage will be altered by subsequent RASTER-processing functions leaving the rest of the image unchanged. Currently, the left and right borders of this subimage must be at bit column intervals, which are multiples of 32 for ease in unpacking data stored in STARAN arrays; the top and bottom borders may be arbitrarily set at any scan line. In the future, this restriction on the vertical borders will be changed to enable the user to select any subimage, including irregularly shaped subimages.

## PROJECTED USES FOR THE RASTER PM

At ETL, the RASTER PM has been used to cleanse images from a number of projects in the areas of classification and edge detection studies. The following paragraphs demonstrate how RASTER cleansing has been used in these areas, and some proposed uses of the program for the near future are discussed.

### Raster Usage With Edge Detection Data

Marr Edge Detector. ETL has performed experiments using the Marr edge detector<sup>3</sup> with various sizes of windows — the larger the window, the less clutter, but the higher the computer cost. Smaller windows still identify linear features, but with a large clutter content as can be seen in the image of Phoenix below (refer to figure 1 for gray shade image) which was processed with a relatively small window size of 7 by 7 and a sigma value of 1 in an effort to identify drainage patterns (figure 8).

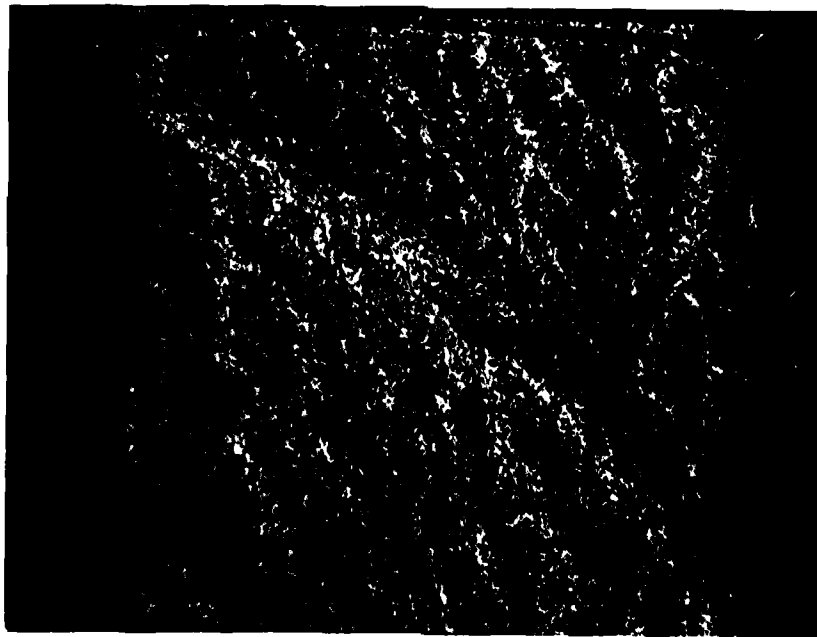
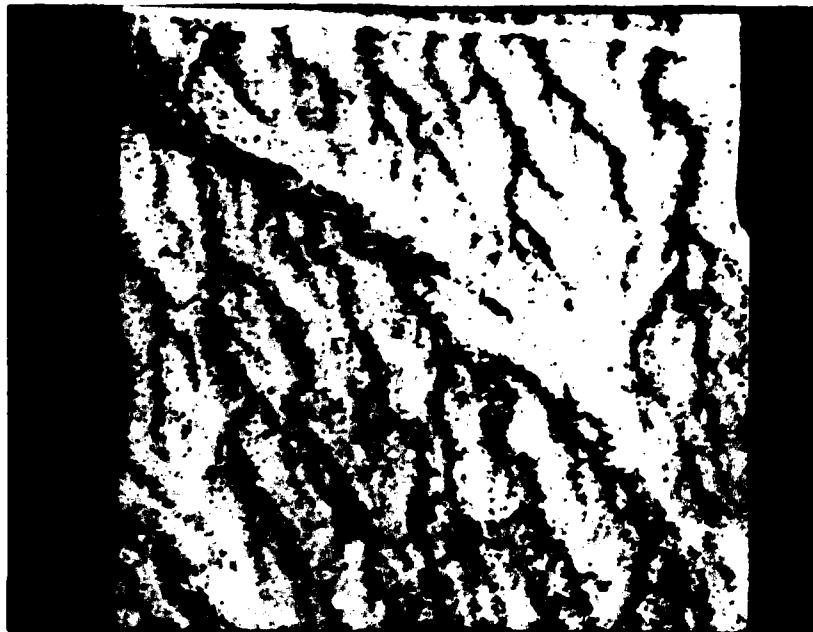


Figure 8. Marr edge detection image of Phoenix, Arizona, using a 7 by 7 window,  $\sigma = 1$

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<sup>3</sup>Jane M. Brown, Analysis of Edge Detection Algorithms on DIAL, U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, Report in progress.

This clutter is then removed using various combinations of RASTER functions to yield the image seen in figure 9. Further improvements can be made to this processed imagery when the option for irregular subimage processing is added.



**Figure 9. RASTER-processed Marr edge detector image overlaid on 8-bit image of Phoenix.**

Detail found on an image stored in binary format, such as the RASTER-processed images, can be mapped onto an image or onto its stereomate. Mapping onto the image would present visual verification of the feature extraction operation. Mapping the binary image to its stereomate would enable the photointerpreter to fill in missing detail as well as to verify and evaluate the x-parallax function.

**Thresholding.** Experiments are being conducted at ETL to determine if simple techniques such as thresholding average gray shades and standard deviations of gray shades in combination with post RASTER processing will identify linear features.

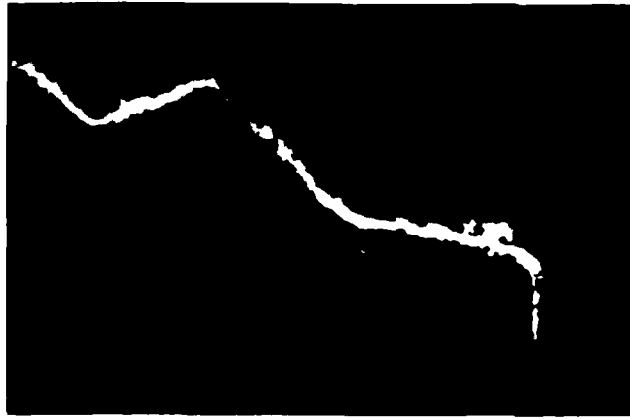
Simple thresholding of the gray shade for each pixel proved successful in identifying basic linear features such as roads and creeks. Some results are shown in figure 10 in thresholding gray shade followed by RASTER-processing these images.



A.



B.



C.

- A. Gray Shade Image
- B. Threshold Creek
- C. Raster-Processed Version of B

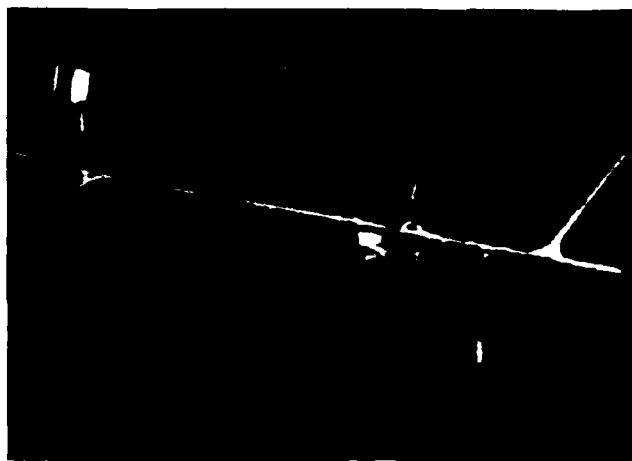
Figure 11. Demonstration of thresholding to identify a creek.



A.



B.



C.

- A. Gray Shade Image
- B. Thresholded Road
- C. Raster-processed Version of B

Figure 10. Demonstration of thresholding to identify a road.

These easily identified linear features can then be entered as input to guide interest operators, such as the Moravec operator, in locating building structures or other items of interest along these roads. Additionally, these linear features may be entered as boundaries for classification studies as often linear features are natural separators of different classes.

The idea of thresholding an image is being expanded further to determine if thresholding average gray shade and standard deviation of a windowed image is suitable for segmentation of an image (see appendix). Studies were conducted using a 2 by 2 window yielding the results shown in figures 12 and 13.

Research will continue in the area of threshold studies to improve results by selecting different window sizes, by studying which thresholds are optional and by examining the effects of the image resolution.



Gray Shade

Threshold of Average  
Gray Shade and Standard Deviation

Figure 12. Thresholding average gray shade and standard deviation using a 2 by 2 window.



Figure 13. RASTER-Processed version of figure 12.

**RASTER Usage with Classification Studies.** A variety of texture algorithms have been experimented with at ETL from complex algorithms like Max-Min<sup>4</sup> and Laws<sup>5</sup> to simple Ad Hoc measures like average gray shade and standard deviation<sup>6</sup>. Regardless of the texture algorithm used, binary images can be generated for each of the classes assigned. These binary images can then be cleansed via RASTER processing to eliminate clutter and misclassified points. Typical results are shown in the following images using the Max-Min texture algorithm followed by RASTER processing (figures 14 through 17).

---

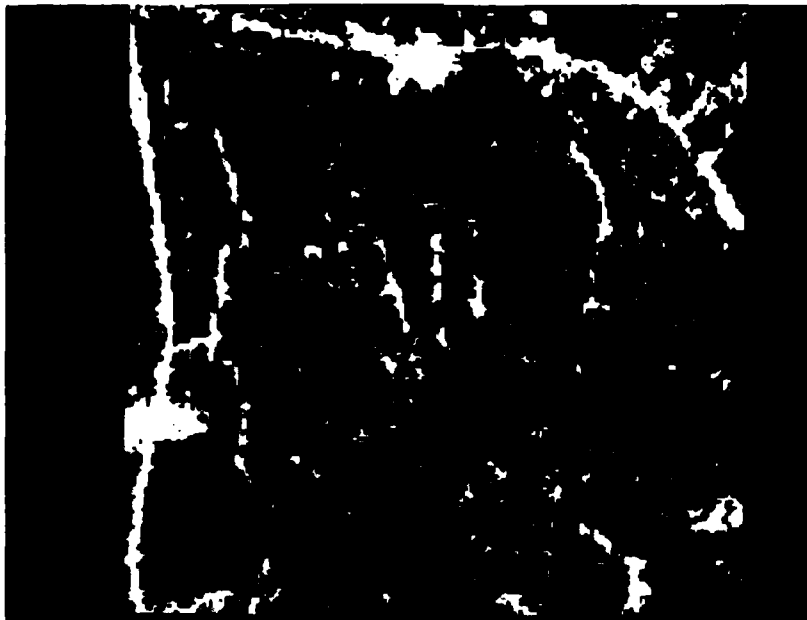
<sup>4</sup>Michael A. Crombie, Robert S. Rand, and Nancy J. Friend, An Analysis of the MAX-MIN Texture Measure, U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0280, January 1982, AD-A116 768.

<sup>5</sup>Robert S. Rand and James Shine, Feature Analysis and Reduction of the Laws Texture Measure, U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0343, October 1983.

<sup>6</sup>Michael A. Crombie, Nancy J. Friend, and Robert S. Rand, Feature Component Reduction Through Divergence Analysis, U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0305, October 1982, AD-A123 474.



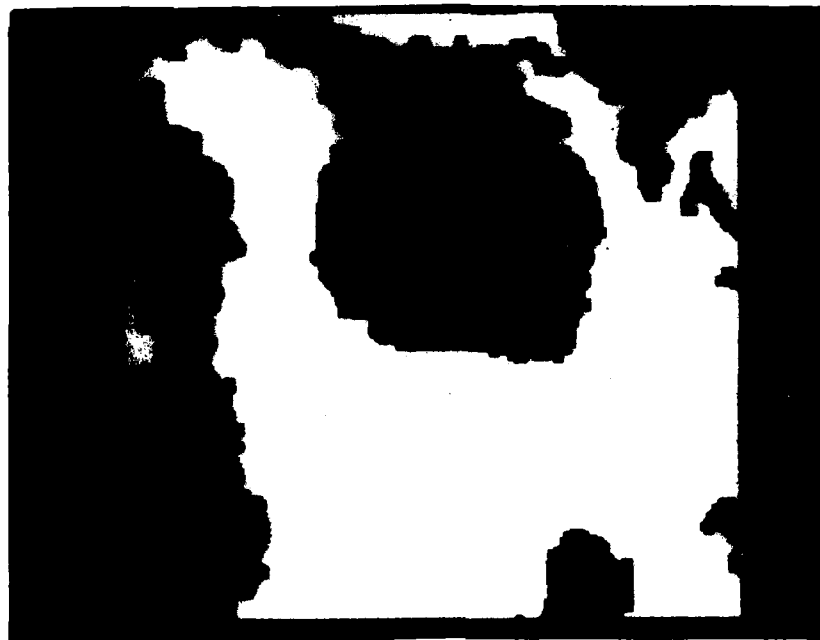
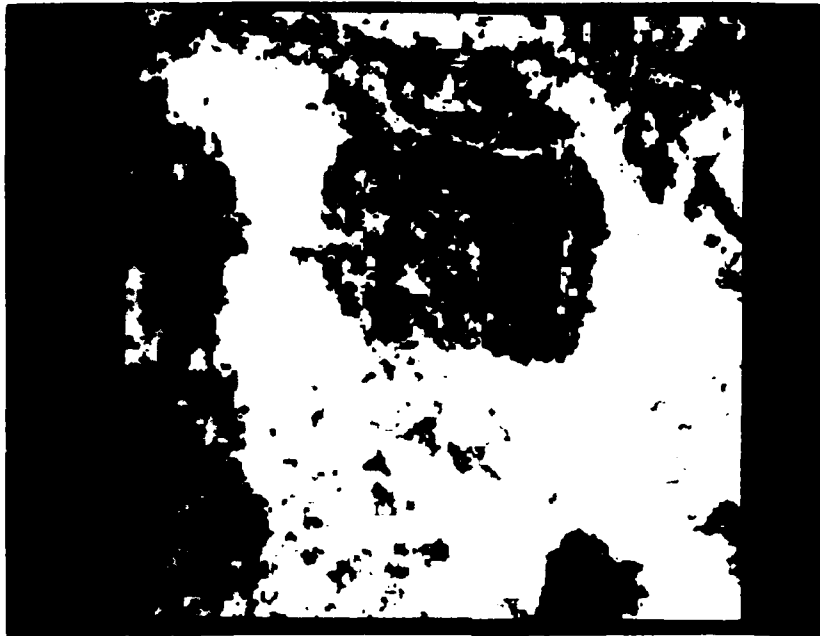
**Figure 14. Canadian Border, Scene A, Pan.**



**Figure 15. Before and after RASTER processing the road class.**



Figure 16. Before and after RASTER processing the field class.



**Figure 17. Before and after RASTER processing the forest class.**

## DISCUSSION

The RASTER PM has proved to be an effective, fast, easily operated image-cleansing algorithm. A few problems, however, were encountered with the initial version of the RASTER PM.

The major problem encountered was that the central memory requirement was so large no other user could operate simultaneously. More efficient use of extended core storage (ECS) will be made in a modification to the program to alleviate this problem.

Another problem encountered with the original RASTER PM was the inflexibility of the subimaging routine. This will be changed to allow subimaging of irregularly shaped regions.

Two additional functions were requested to be coded by GAC. The first would be to connect areas whose endpoints are close and whose principal axes run in the same direction (directional line growing). The second is for a conversion routine to convert the raster data to vector format for subsequent use with other programs.

It is expected that these four changes will be operational by Fall 1983.

## CONCLUSIONS

1. The RASTER PM has proved to be an effective, fast, easily operated program for image cleansing.
2. Implementation of a program modification to alleviate central memory requirements will make more efficient use of ECS.
3. Rectangular subimaging is too restrictive for localized RASTER processing and will be changed to allow irregularly shaped subimaging.

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Crombie, Michael A.; Rand, Robert S.; and Friend, Nancy J., "An Analysis of the MAX-MIN Texture Measure", U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0280, January 1982, AD-A116 768.

Crombie, Michael A.; Rand, Robert S.; and Friend, Nancy J., "Scene Classification Results Using the MAX-MIN Texture Measure", U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0300, July 1982, AD-A123 496.

Crombie, Michael A.; Friend, Nancy J.; and Rand, Robert S., "Feature Component Reduction Through Divergence Analysis", U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0305, July 1982, AD-A123 474.

Rand, Robert S.; and Shine, James, "Feature Analysis and Reduction of the Law's Texture Measure", U.S. Army Engineer Topographic Laboratories, Fort Belvoir, VA, ETL-0343, October 1983.

**Appendix. METHOD FOR THRESHOLDING AVERAGE  
AND STANDARD DEVIATION OF GRAY SHADE.**

For each 2 x 2 window, compute

$g_{ij}$  and  $s_{ij}$   $i = 1, \text{ image size } n$   
 $j = 1, \text{ image size } n$

$$g_{ij} = 1/4 A_{ij}$$

$$s_{ij} = \frac{\sqrt{4 B_{ij} - A_{ij}^2}}{\sqrt{12}}$$

where

$$A_{ij} = \sum_{l=1}^2 \sum_{p=1}^2 glp \quad glp = \text{gray level for pixel } (lp)$$

$$B_{ij} = \sum_{l=1}^2 \sum_{p=1}^2 glp^2$$

Set the horizontal boundary value to 1 if

$$g_{ij} - g_{ij+1} \geq Cg$$

and

$$s_{ij} - s_{ij+1} > Cs$$

or

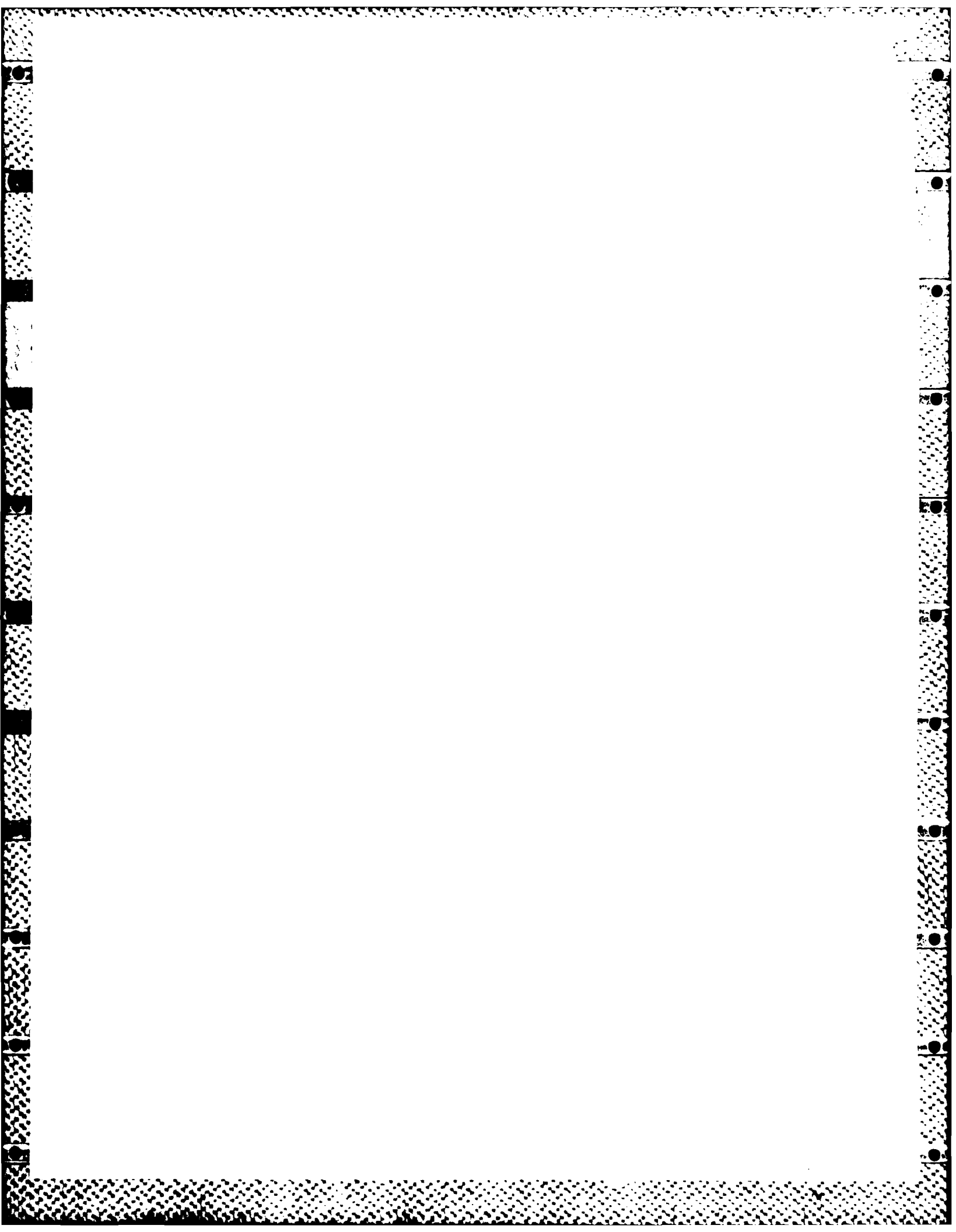
set the vertical boundary value to 1 if

$$g_{ij} - g_{i+1, j} > Cg$$

and

$$s_{ij} - s_{i+1, j} > Cs$$

where  $Cg$  and  $Cs$  are experimentally derived threshold values for average and standard deviation of gray shades.



END

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